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Zhang

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(54) **METHOD AND SYSTEM FOR AN ASPIRATOR FOR A BRAKE BOOSTER**

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B60T 13/52	(2006.01)
F01P 1/06	(2006.01)
F01P 5/02	(2006.01)

(52) **U.S. Cl.**

CPC ***B60T 13/52*** (2013.01); ***F01P 1/06*** (2013.01); ***F01P 5/02*** (2013.01)

(58) **Field of Classification Search**

CPC F02B 33/446; F02B 33/44; F02D 41/0007; F02M 35/10032; F02M 35/10091; F04F 5/20; F04F 5/24; B60T 13/46; B60T 13/52; B60T 17/02

USPC 123/559.1, 564–567, 184.21, 123/184.24–184.26; 60/598, 600

See application file for complete search history.

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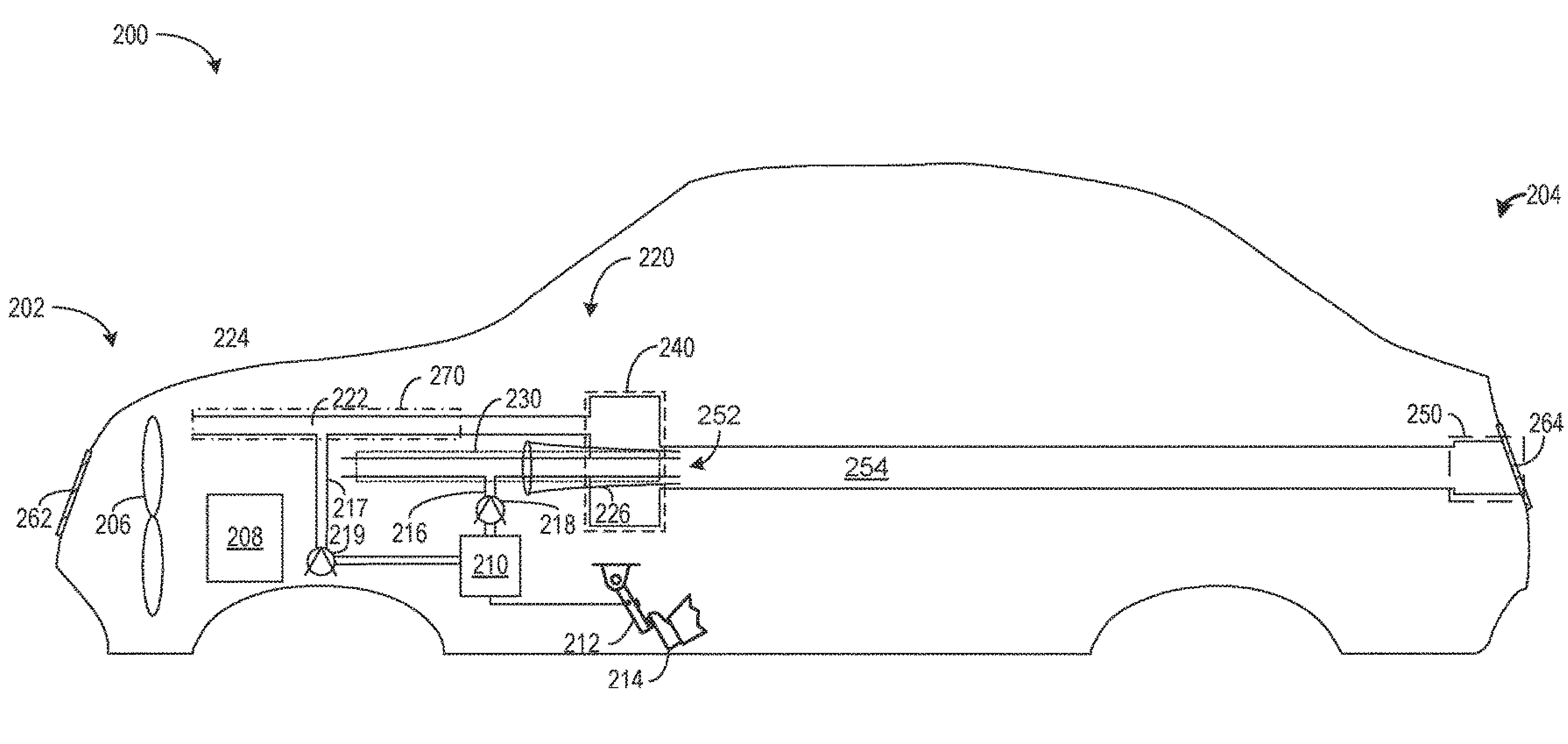
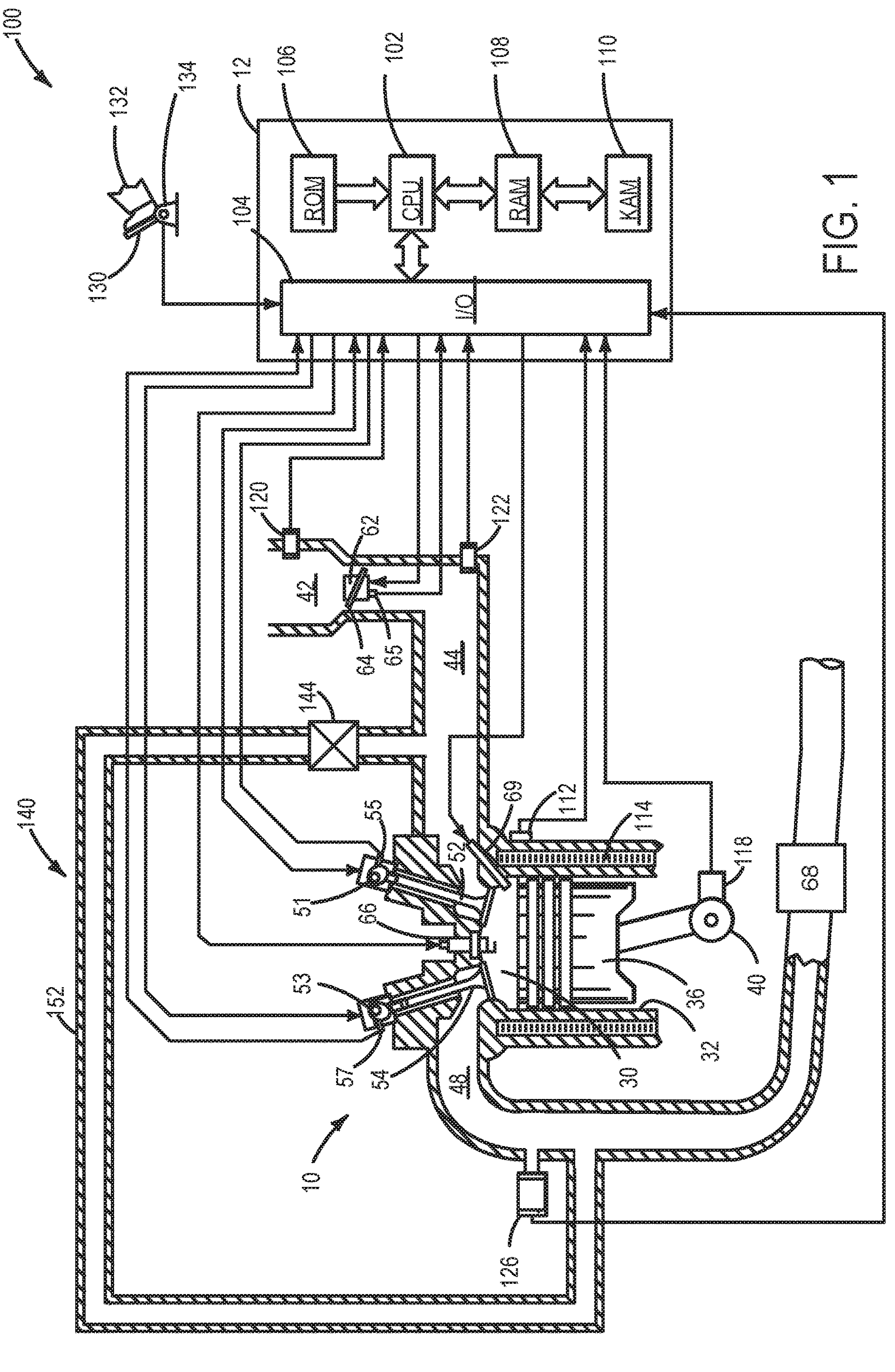
(57) **ABSTRACT**

Methods and systems are provided for providing vacuum to a brake booster via an aspirator system. In one example, a system may include an aspirator system fluidly coupled with a brake booster with no intervening components located therebetween.

16 Claims, 5 Drawing Sheets





100
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KAM
I/O
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44
144
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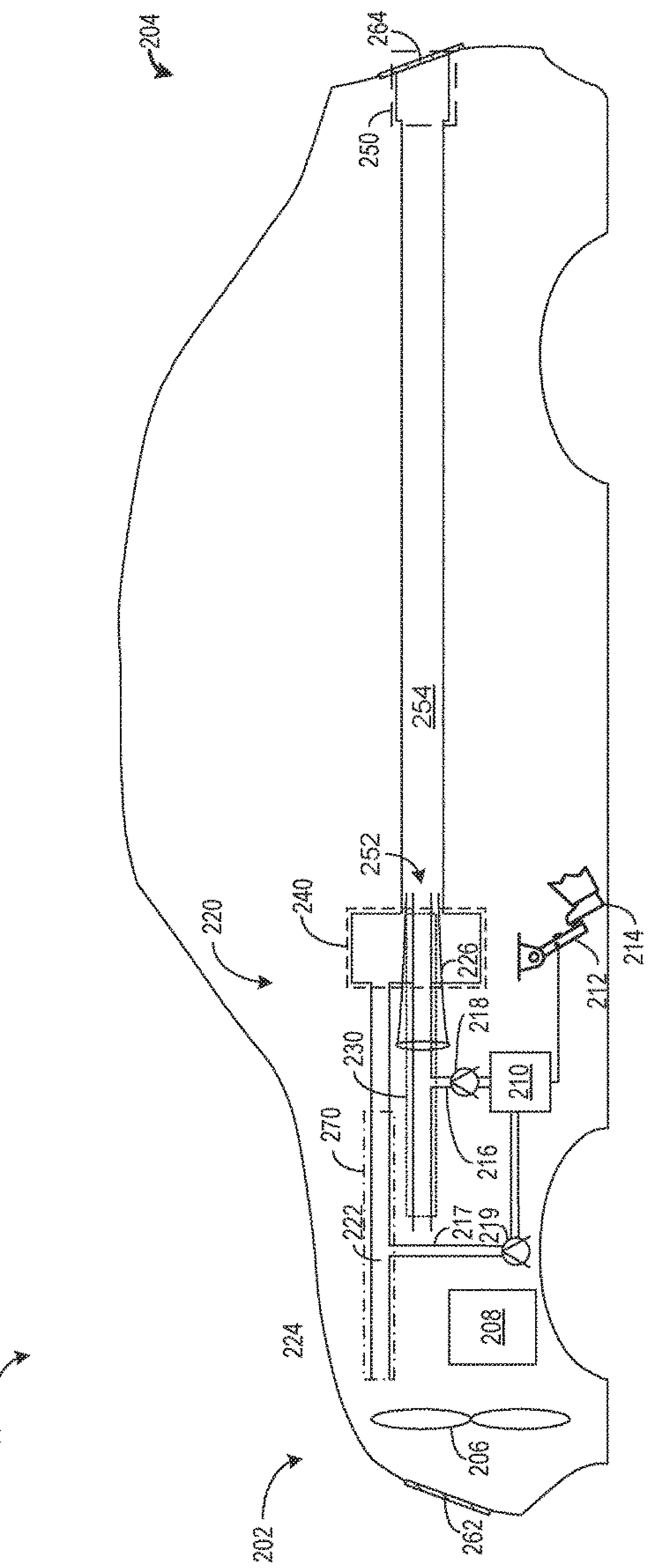
10
126

FIG. 1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264
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252
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222
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FIG. 2
200

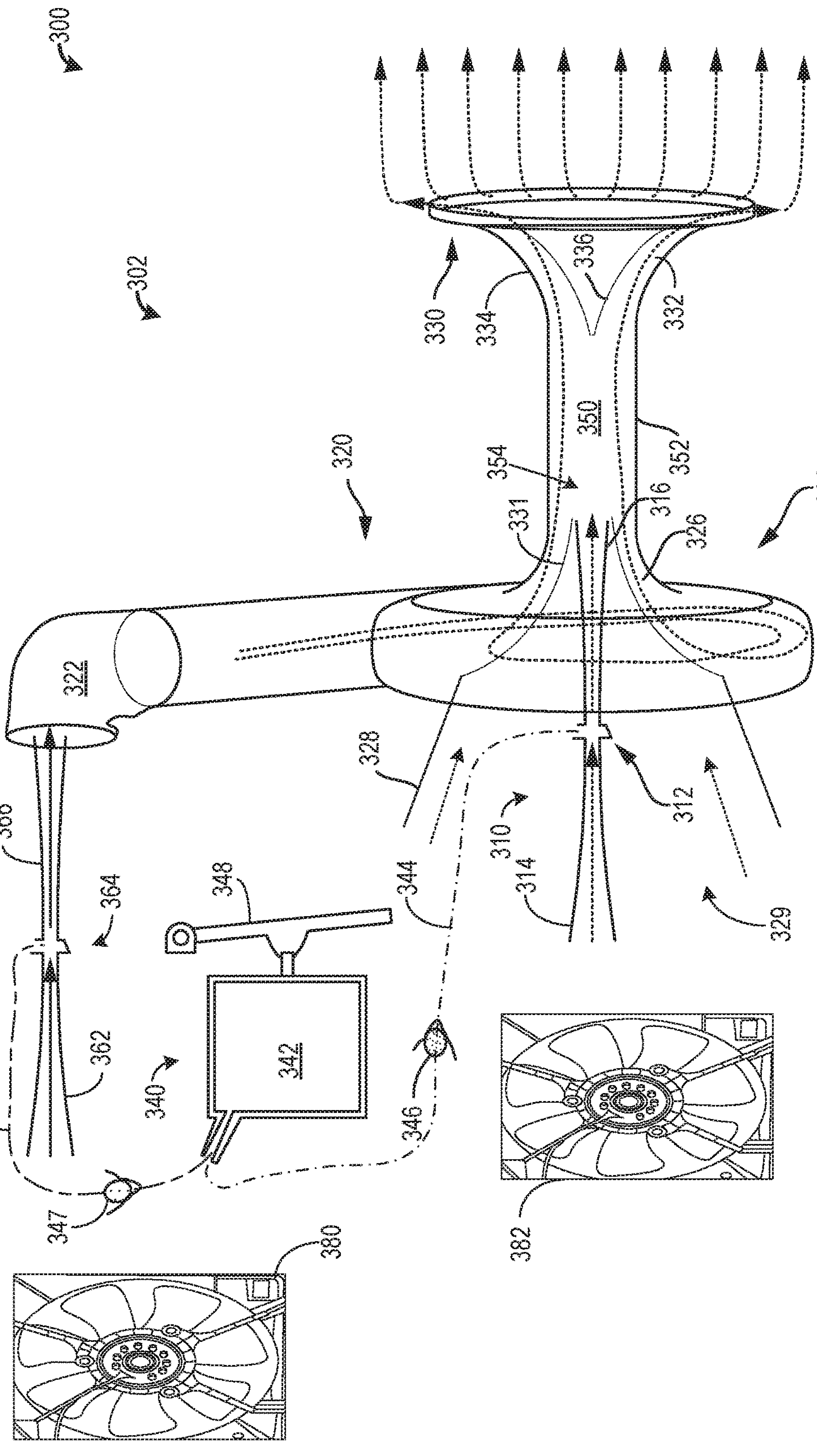
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FIG. 3

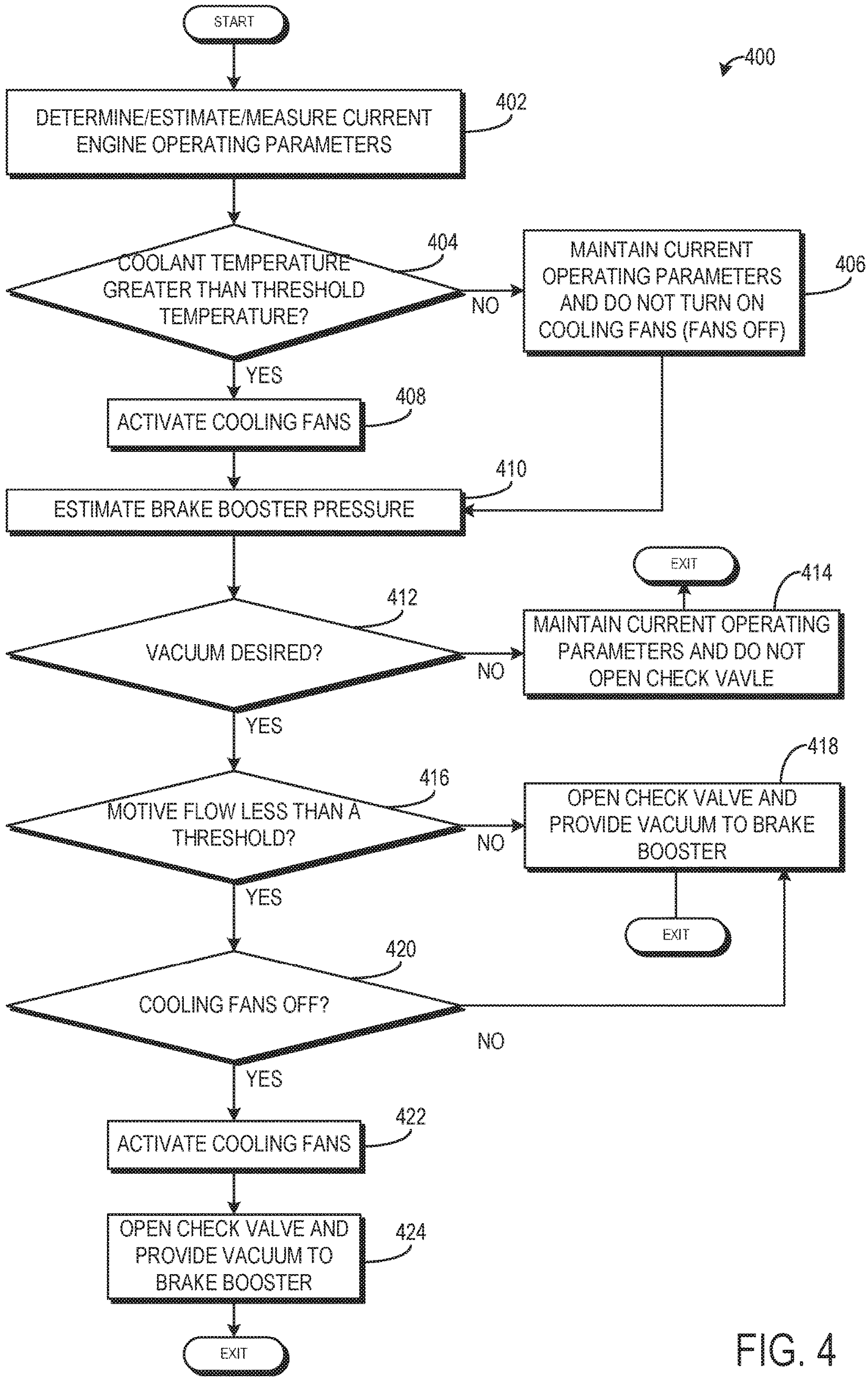
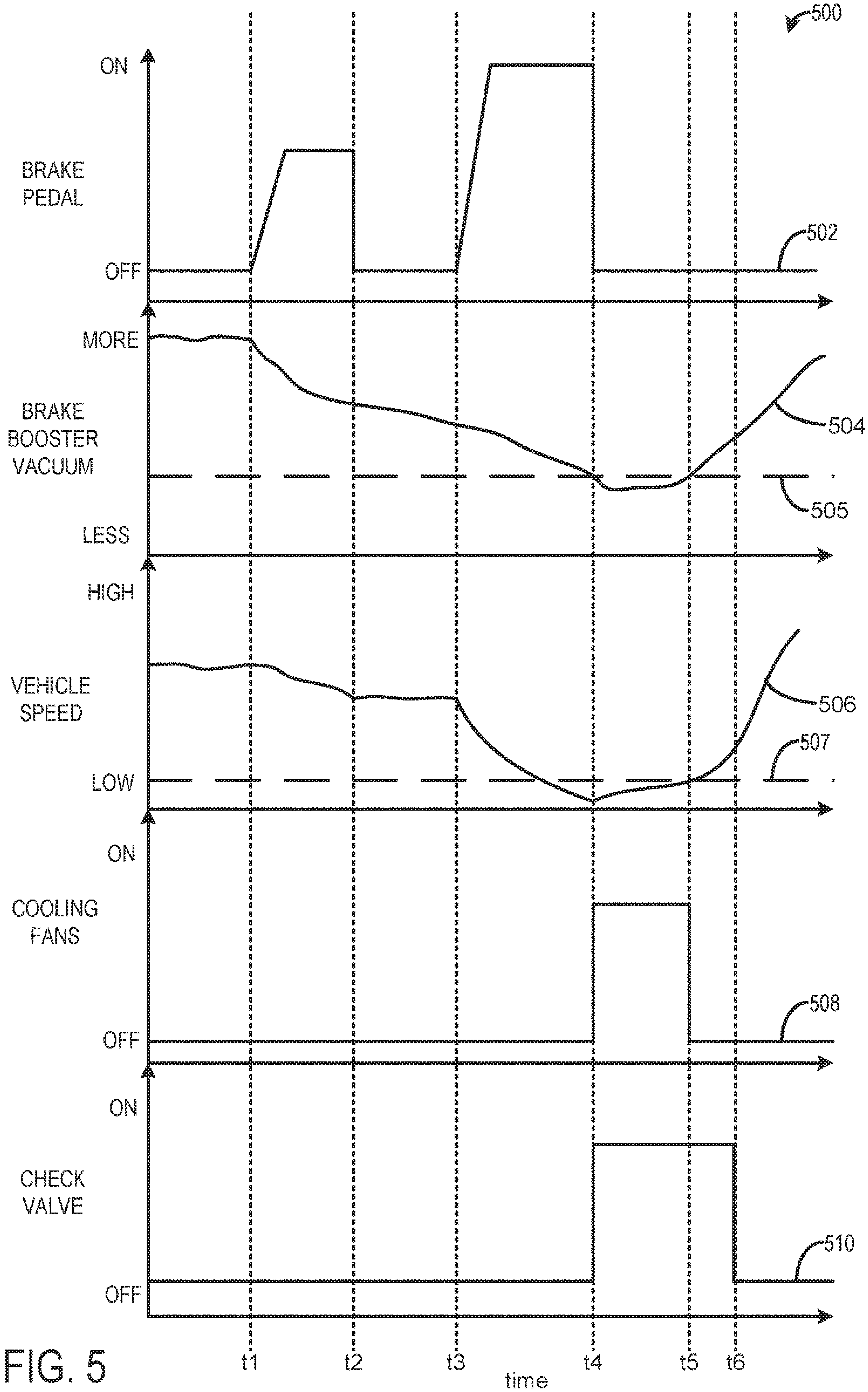

START
400
DETERMINE/ESTIMATE/MEASURE CURRENT ENGINE OPERATING PARAMETERS
402
COOLANT TEMPERATURE GREATER THAN THRESHOLD TEMPERATURE?
404
NO
MAINTAIN CURRENT OPERATING PARAMETERS AND DO NOT TURN ON COOLING FANS (FANS OFF)
406
YES
ACTIVATE COOLING FANS
408
ESTIMATE BRAKE BOOSTER PRESSURE
410
EXIT
414
VACUUM DESIRED?
412
NO
MAINTAIN CURRENT OPERATING PARAMETERS AND DO NOT OPEN CHECK VAVLE
YES
MOTIVE FLOW LESS THAN A THRESHOLD?
416
NO
OPEN CHECK VALVE AND PROVIDE VACUUM TO BRAKE BOOSTER
418
EXIT
YES
COOLING FANS OFF?
420
NO
YES
ACTIVATE COOLING FANS
422
OPEN CHECK VALVE AND PROVIDE VACUUM TO BRAKE BOOSTER
424
EXIT

FIG. 4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BRAKE
PEDAL
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BRAKE
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COOLING
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510
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t3
t4
t5
t6
time

FIG. 5

METHOD AND SYSTEM FOR AN ASPIRATOR FOR A BRAKE BOOSTER

CROSS REFERENCE TO RELATED APPLICATION

The present application is a continuation-in-part of U.S. patent application Ser. No. 14/941,238, "METHOD AND SYSTEM FOR AN ASPIRATOR FOR A BRAKE BOOSTER," filed on Nov. 13, 2015, the entire contents of which are incorporated herein by reference for all purposes.

FIELD

The present description relates generally to an aspirator for a brake booster.

BACKGROUND/SUMMARY

Vehicle control systems may be configured to start an engine assuming a given intake manifold volume. However, interactions between vacuum levels in a brake booster and the intake manifold pressure at engine starts can cause variability in the air charge, and consequently air-to-fuel ratio at the engine starts. As such, this increases exhaust emissions.

One approach to address this variability is shown by Kayama et al. in U.S. Pat. No. 6,857,415. Therein, a valve is placed between the brake booster and the intake manifold to equalize the (remaining) pressure in the brake booster to atmospheric levels or to remove air from the intake manifold to the brake booster.

However, the inventors herein have identified a potential issue with such an approach. As one example, the valve used in the approach of Kayama et al. does not allow the level of intake manifold pressure (MAP) to be set from one engine start to another engine start. As another example, even with the valve, a consistent MAP level may not be attained at engine starts occurring at high altitudes as well as at sea level. Further, the valve may be controlled by a control system with electric signals which may increase an overall cost of production.

In one example, the issues described above may be addressed by an aspirator system comprising a volute-shaped aspirator with a linear aspirator protruding through a spiral of the volute aspirator, the volute aspirator comprising a first venturi passage and the linear aspirator comprising a second venturi passage and where the passages are fluidly coupled to a brake booster, and where the aspirators are fluidly coupled to front or rear grills with no other intervening components located therebetween. In this way, vacuum may be provided to the brake booster without flowing suck flow from the brake booster to an engine or any components of the engine.

As one example, the aspirators receive motive flow through the front grill and generate vacuum based on geometries of the linear aspirator, the volute aspirator, and a conical aspirator. The vacuum may be provided to the brake booster when the check valve is open based on a vacuum of the brake booster being less than a minimum threshold vacuum. The vacuum draws suck flow from the brake booster to the aspirator system. The suck flows mixes with the motive flow and flows through the aspirators and out the rear grill without flowing through any other components.

It should be understood that the summary above is provided to introduce in simplified form a selection of concepts that are further described in the detailed description. It is not meant to identify key or essential features of the claimed subject matter, the scope of which is defined uniquely by the claims that follow the detailed description. Furthermore, the claimed subject matter is not limited to implementations that solve any disadvantages noted above or in any part of this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an example engine with a single cylinder.

FIG. **2** shows a vehicle comprising the engine and an aspirator system coupled to a brake booster.

FIG. **3** shows a shape of first, second, third and fourth aspirator geometries of the aspirator system.

FIG. **3** is shown approximately to scale, although other relative dimensions may be used.

FIG. **4** shows a method for providing vacuum to the brake booster.

FIG. **5** shows a chart detailing vacuum level in the brake booster based on vehicle conditions.

DETAILED DESCRIPTION

The following description relates to an example of an aspirator system for providing vacuum to a brake booster. A general schematic of an engine is shown in FIG. **1**. A vehicle with the engine and the aspirator coupled to the brake booster is shown in FIG. **2**. First, second, third, and fourth aspirator portions are shown in detail in FIG. **3**. The portions may fluidly communicate with one another while being fluidly separated from the engine. The first portion is fluidly coupled to the brake booster when one or more check valves are in an open position. The aspirator system may draw suck flow from the brake booster while providing vacuum to the brake booster. The suck flow may mix with motive flow in the aspirator system and flow out the aspirator system without flowing to any intervening components therebetween. A method for providing vacuum to the brake booster is shown in FIG. **4**. A chart showing brake booster vacuum level changes based on vehicle operations is shown in FIG. **5**.

FIG. **3** shows example configurations with relative positioning of the various components. If shown directly contacting each other, or directly coupled, then such elements may be referred to as directly contacting or directly coupled, respectively, at least in one example. Similarly, elements shown contiguous or adjacent to one another may be contiguous or adjacent to each other, respectively, at least in one example. As an example, components laying in face-sharing contact with each other may be referred to as in face-sharing contact. As another example, elements positioned apart from each other with only a space there-between and no other components may be referred to as such, in at least one example.

Continuing to FIG. **1**, a schematic diagram showing one cylinder of a multi-cylinder engine **10** in an engine system **100**, which may be included in a propulsion system of an automobile, is shown. The engine **10** may be controlled at least partially by a control system including a controller **12** and by input from a vehicle operator **132** via an input device **130**. In this example, the input device **130** includes an accelerator pedal and a pedal position sensor **134** for generating a proportional pedal position signal. A combustion chamber **30** of the engine **10** may include a cylinder formed by cylinder walls **32** with a piston **36** positioned therein. The piston **36** may be coupled to a crankshaft **40** so that reciprocating motion of the piston is translated into rotational motion of the crankshaft. The crankshaft **40** may be coupled to at least one drive wheel of a vehicle via an intermediate transmission system. Further, a starter motor may be coupled to the crankshaft **40** via a flywheel to enable a starting operation of the engine **10**.

The combustion chamber **30** may receive intake air from an intake manifold **44** via an intake passage **42** and may exhaust combustion gases via an exhaust passage **48**. The intake manifold **44** and the exhaust passage **48** can selectively communicate with the combustion chamber **30** via respective intake valve **52** and exhaust valve **54**. In some examples, the combustion chamber **30** may include two or more intake valves and/or two or more exhaust valves.

In this example, the intake valve **52** and exhaust valve **54** may be controlled by cam actuation via respective cam actuation systems **51** and **53**. The cam actuation systems **51** and **53** may each include one or more cams and may utilize one or more of cam profile switching (CPS), variable cam timing (VCT), variable valve timing (VVT), and/or variable valve lift (VVL) systems that may be operated by the controller **12** to vary valve operation. The position of the intake valve **52** and exhaust valve **54** may be determined by position sensors **55** and **57**, respectively. In alternative examples, the intake valve **52** and/or exhaust valve **54** may be controlled by electric valve actuation. For example, the cylinder **30** may alternatively include an intake valve controlled via electric valve actuation and an exhaust valve controlled via cam actuation including CPS and/or VCT systems.

A fuel injector **69** is shown coupled directly to combustion chamber **30** for injecting fuel directly therein in proportion to the pulse width of a signal received from the controller **12**. In this manner, the fuel injector **69** provides what is known as direct injection of fuel into the combustion chamber **30**. The fuel injector may be mounted in the side of the combustion chamber or in the top of the combustion chamber, for example. Fuel may be delivered to the fuel injector **69** by a fuel system (not shown) including a fuel tank, a fuel pump, and a fuel rail. In some examples, the combustion chamber **30** may alternatively or additionally include a fuel injector arranged in the intake manifold **44** in a configuration that provides what is known as port injection of fuel into the intake port upstream of the combustion chamber **30**.

Spark is provided to combustion chamber **30** via spark plug **66**. The ignition system may further comprise an ignition coil (not shown) for increasing voltage supplied to spark plug **66**. In other examples, such as a diesel, spark plug **66** may be omitted.

The intake passage **42** may include a throttle **62** having a throttle plate **64**. In this particular example, the position of throttle plate **64** may be varied by the controller **12** via a signal provided to an electric motor or actuator included with the throttle **62**, a configuration that is commonly referred to as electronic throttle control (ETC). In this manner, the throttle **62** may be operated to vary the intake air provided to the combustion chamber **30** among other engine cylinders. The position of the throttle plate **64** may be provided to the controller **12** by a throttle position signal. The intake passage **42** may include a mass air flow sensor **120** and a manifold air pressure sensor **122** for sensing an amount of air entering engine **10**.

An exhaust gas sensor **126** is shown coupled to the exhaust passage **48** upstream of an emission control device **68** according to a direction of exhaust flow. The sensor **126** may be any suitable sensor for providing an indication of exhaust gas air-fuel ratio such as a linear oxygen sensor or UEGO (universal or wide-range exhaust gas oxygen), a two-state oxygen sensor or EGO, a HEGO (heated EGO), a NO_x, HC, or CO sensor. In one example, upstream exhaust gas sensor **126** is a UEGO configured to provide output, such as a voltage signal, that is proportional to the amount of oxygen present in the exhaust. Controller **12** converts oxygen sensor output into exhaust gas air-fuel ratio via an oxygen sensor transfer function.

The emission control device **68** is shown arranged along the exhaust passage **48** downstream of the exhaust gas sensor **126**. The device **68** may be a three way catalyst (TWC), NO_x trap, selective catalytic reductant (SCR), various other emission control devices, or combinations thereof. In some examples, during operation of the engine **10**, the emission control device **68** may be periodically reset by operating at least one cylinder of the engine within a particular air-fuel ratio.

An exhaust gas recirculation (EGR) system **140** may route a desired portion of exhaust gas from the exhaust passage **48** to the intake manifold **44** via an EGR passage **152**. The amount of EGR provided to the intake manifold **44** may be varied by the controller **12** via an EGR valve **144**. Under some conditions, the EGR system **140** may be used to regulate the temperature of the air-fuel mixture within the combustion chamber, thus providing a method of controlling the timing of ignition during some combustion modes.

The controller **12** is shown in FIG. **1** as a microcomputer, including a microprocessor unit **102**, input/output ports **104**, an electronic storage medium for executable programs and calibration values shown as read only memory chip **106** (e.g., non-transitory memory) in this particular example, random access memory **108**, keep alive memory **110**, and a data bus. The controller **12** may receive various signals from sensors coupled to the engine **10**, in addition to those signals previously discussed, including measurement of inducted mass air flow (MAF) from the mass air flow sensor **120**; engine coolant temperature (ECT) from a temperature sensor **112** coupled to a cooling sleeve **114**; an engine position signal from a Hall effect sensor **118** (or other type) sensing a position of crankshaft **40**; throttle position from a throttle position sensor **65**; and manifold absolute pressure (MAP) signal from the sensor **122**. An engine speed signal may be generated by the controller **12** from crankshaft position sensor **118**. Manifold pressure signal also provides an indication of vacuum, or pressure, in the intake manifold **44**. Note that various combinations of the above sensors may be used, such as a MAF sensor without a MAP sensor, or vice versa. During engine operation, engine torque may be inferred from the output of MAP sensor **122** and engine speed. Further, this sensor, along with the detected engine speed, may be a basis for estimating charge (including air) inducted into the cylinder. In one example, the crankshaft position sensor **118**, which is also used as an engine speed sensor, may produce a predetermined number of equally spaced pulses every revolution of the crankshaft.

The storage medium read-only memory **106** can be programmed with computer readable data representing non-transitory instructions executable by the processor **102** for performing the methods described below as well as other variants that are anticipated but not specifically listed.

The controller **12** receives signals from the various sensors of FIG. **1** and employs the various actuators of FIG. **1** to adjust engine operation based on the received signals and instructions stored on a memory of the controller.

FIG. **2** shows a vehicle **200** comprising an engine **208** with a fan **206** (herein cooling fan). The engine **208** may be used similarly to engine **10** of FIG. **1**. The vehicle **200** further comprises a front end **202** and a back end **204**. The engine **208** and the cooling fan **206** are proximal to the front end **202**. The vehicle **200** further comprises a front grill **262** and a rear grill **264** which may admit motive flow at the front end **202** and expel motive flow from the vehicle at the back end **204**, respectively.

Coolant temperatures may rise during low vehicle speeds and/or idle when motive air through a radiator of the engine **208** is unable to sufficiently cool engine coolant. In response to the insufficient motive air, the cooling fan **206** may be activated to decrease a temperature of the engine and/or its components. In this way, the cooling fan **206** may be activated during low vehicle speeds. It will be appreciated by someone skilled in the art that the fan **206** may also be activated during higher vehicle speeds in order to cool the engine **208** and/or one or more of its components. There may be more than one fan in some embodiments without departing from the scope of the present disclosure. The cooling fan **206** may be activated in response to a coolant temperature exceeding a threshold temperature. The temperature threshold may be based on a temperature where the coolant may no longer sufficiently cool an engine and/or one or more engine components described in the embodiment of FIG. **1**.

A brake booster **210** is shown coupled to a brake pedal **212**. The brake booster **210** may include an internal vacuum reservoir to amplify force provided by a foot **214** to the brake pedal **212**. Vacuum is consumed when the pedal **212** is depressed resulting in a pressure increase (or loss of vacuum) in the brake booster. Thus, the brake booster **210** is fluidly connected to at least a portion of an aspirator system **220**. The aspirator system **220** may be a single contiguous component or it may be a plurality of components coupled together by suitable coupling means, such as welds, adhesives, etc. for example. The aspirator system **220** comprises four portions namely, a first portion **230**, a second portion **270**, a third portion **240**, and a fourth portion **250**. The portions may build a vacuum strength through a body of the aspirator system **220** such that vacuum is generated in series through the system as air flows through features of the aspirator system. The aspirator system **220** is fluidly connected to only the brake booster **210** and is fluidly separated from other systems of the vehicle **200**. The aspirator system may receive motive flow through at least the first **230** and second **270** portions and expel the motive flow through the fourth portion **250**. The fourth portion **250** may generate the strongest vacuum due to ambient air flowing by an outlet of the fourth portion at speeds similar to a speed of the vehicle **200**, thereby drawing air out of the fourth portion **250**. The increased speed of the ambient air draws motive flow from the fourth portion **250** and generates a vacuum in the fourth portion, where the vacuum in the fourth portion is used to draw motive air from the first **230**, second **270**, and third **240** portions, as will be described below.

The fourth aspirator portion **250**, indicated by large dashed lines, may be cone-shaped, however, the fourth aspirator portion may be other annular shapes (e.g., cylindrical) without departing from the scope of the present disclosure. As described above, the fourth portion **250** may expel motive air through the rear grill **264** adjacent the rear end **204** into an ambient atmosphere. The fourth aspirator portion **250** generates a first vacuum strength due to features and/or geometries of the fourth aspirator portion, as shown in FIG. **3**. In one example, the first vacuum strength may be 5 kPa. The fourth aspirator portion is fluidly coupled to a region of confluence **252** via a channel **254**. Motive flow from at least the first **230**, second **270**, and third **240** may merge in the region of confluence **252**, before being drawn to the fourth portion **250**. Thus, the region of confluence **252** is located adjacent to outlets of the first **230**, second **270**, and third **240** portions. Furthermore, motive flow from a conical pipe **226** may also mix with motive flows of the portions at the region of confluence **252**.

The third aspirator portion **240**, indicated by medium dashed lines, may be a volute shape (similar to a turbine) fluidly coupled to the second aspirator portion **270**. For example, the third aspirator portion **240** receives motive flow from the second aspirator portion **270** and expels the motive flow to the region of confluence **252**. Furthermore, the third aspirator portion **240** may be a single pipe, spiraling around a portion of the first aspirator portion **230** and the conical pipe **226**, transitioning into the channel **254**. However, as shown, the first aspirator portion **230** and the conical pipe **226** span an entire length of the third aspirator portion **240** such that air from the first aspirator portion and the conical pipe do not flow into the third aspirator portion **240**, but merge with air from the third portion at the region of confluence **252**.

A majority of motive air flowing to the region of confluence **252** may be provided by the conical pipe **226**. Thus, a size of an inlet of the conical pipe **226** is greater than a size of an inlet (second inlet **222**) of the second portion **270** and a size of an inlet (first inlet **224**) of the first portion **230**. In one example, the conical pipe **226** may receive 20-30 g/s of ambient air for a vehicle traveling at 40 miles per hour.

The second portion **270**, indicated by a dash-dot line, may be a venturi shape with an outlet fluidly connected to an inlet of the third portion **240**. The second **270** and third **240** portions are configured such that flow through the third portion generates a vacuum which may supplement vacuum developed in a narrowest portion of the venturi passage of the second portion. The second portion **270** may directly receive motive flow from one or more of the front grill **262** and the fan **206** via a second inlet **222**. The second inlet **222** is smaller than the conical pipe **226** and receives less motive air. The first portion **230**, indicated by a small dashed line, may also be a venturi shape with an outlet of the venturi fluidly coupled with the region of confluence **252**. In one example, the venturi passages of the second **270** and first **230** portions are substantially equal, as are their inlets **222** and **224**, respectively. Substantially equal may be defined as the venturi passages deviating from each other due to stress induced tolerances by 1-5% in one example. Motive flow provided to the second **222** and first **224** inlets may be fluidly separate from the motive flow provided to the engine **208**. An outlet of the venturi of the first portion **230** may be surrounded by the outlet of the conical pipe **226**. In this way, the conical pipe may supplement vacuum strength generated in a narrowest portion of the venturi passage of the first portion.

Thus, the fourth portion **250** expels motive flow from aspirator system **220** to the ambient atmosphere to generate a first vacuum, where the first vacuum may supplement vacuum generation for the first **230**, second **270**, and third **240** portions upstream of the fourth portion **250**. The third portion **240** comprises features for aiding vacuum generation in the second portion **270**, where vacuum generation in the second portion is further supplemented by the first vacuum. The conical pipe **226** is configured to aid vacuum generation in the first portion **230**, where the vacuum generation in the first portion is further supplemented by the first vacuum. In this way, vacuum may be generated in series through the aspirator system **220** by flowing motive flow through the aspirator system without flowing the motive flow to other components of the vehicle **200**.

A first vacuum line **216** with a first check valve **218** couples the brake booster **210** to the first aspirator portion **230**. The aspirator system **220** may provide vacuum to replenish the vacuum of the brake booster when the first check valve **218** is open. The first vacuum line **216** may be coupled to the narrowest portion of the venturi passage of the first aspirator portion **230**. Likewise, a second vacuum line **217** with a second check valve **219** couples the brake booster **210** to a second aspirator portion **270**. The second aspirator portion **270** may provide vacuum to replenish the vacuum of the brake booster when the second check valve **219** is open. The second vacuum line **217** may be coupled to the narrowest portion of the venturi passage of the second aspirator portion. The first **218** and second **219** check valves simultaneously open when the vacuum of the brake booster **210** is less than a minimum threshold vacuum. The minimum threshold vacuum may be based on a vacuum generated in a first **230** or second **270** portion (e.g., 40000 Pa). For example, if the vacuum of the brake booster is 50000 Pa, then the first **218** and second check **219** valves may open and provide vacuum to the brake booster **210** from the first **230** and second **270** portions. As one example, the vacuum of the brake booster **210** may decrease in response to the brake pedal **212** being depressed, and as a result, the check valves **218** and **219** may open in response to the brake pedal being depressed. In this way, the first **216** and second **217** vacuum lines supply vacuum to the brake booster **210** simultaneously, which may increase a rate of vacuum replenishment supplied to the brake booster. In some embodiments, the first and second check valves may open in response to different vacuum thresholds of the brake booster **210**. The check valves **218** and **219** may remain in a closed position if the vacuum of the brake booster is greater than the minimum vacuum threshold to prevent fluid communication (vacuum leakage) between the booster **210** and first **230** and second **270** aspirator portions.

When the check valves **218** and **219** are open and the first **230** and second **270** portions provide vacuum to the brake booster **210**, suck flow from the brake booster flows into the portions and mixes with motive flow. The mixture may then flow through the aspirator system **220** before flowing through the rear grills **264**, without flowing to the engine or any engine components.

During instances of low motive flow, the cooling fan **206** may be activated to provide motive flow through the first **224** and second **222** inlets and the conical pipe **226**. In this way, vacuum may be provided by the aspirator system **220** to the brake booster **210** independent of a vehicle speed.

As an example, the vehicle may use stored vacuum within the brake booster while depressing the brake pedal to slow from a high speed to a stop/low speed. If the vacuum within the brake booster decreases below the minimum threshold vacuum, then the check valves may open, indicating a demand to provide vacuum to the brake booster. As an operator accelerates the vehicle from the stop, the motive air may be insufficient to generate sufficient vacuum in the aspirator system to replenish vacuum to the brake booster. Thus, the cooling fan may be activated to provide all of or a portion of the motive air through the aspirator system to generate vacuum. In this way, the cooling fan may be used to both cool the engine and/or one or more engine components and provide motive air to the aspirator system. The cooling fan may be deactivated in response to a vehicle speed generating a motive flow greater than a threshold flow or to a coolant temperature decreasing below the threshold temperature. If the coolant temperature decreases below the threshold temperature while the motive flow is less than the threshold flow, the cooling fan may be deactivated to prevent further coolant temperature decrease in a first condition. In a second condition, the cooling fan may remain active in response to the coolant temperature being below the threshold temperature and the motive flow being less than the threshold flow to provide vacuum to the brake booster. In some examples, multiple fans may be present wherein a first fan may be disabled and a second fan may remain active in response to the coolant temperature decreasing below a decreasing below the threshold temperature.

Additionally or alternatively, the aspirator system may provide vacuum to the brake booster simultaneously to the vehicle using vacuum stored within the brake booster. The aspirator system continuously receives motive flow during vehicle motion and may receive motive flow during vehicle stops from the cooling fan(s). Thus, the aspirator system may continuously generate vacuum independent of the brake booster desiring vacuum. If the brake booster desires vacuum while the brake pedal is depressed, then the check valve may open to fluidly connect the brake booster to the aspirator system. In this way, vacuum of the brake booster may be replenished while braking with assistance from the brake booster.

As depicted, the aspirator system **220** and the brake booster **210** are not in fluid communication with the engine **208** and/or any engine components such as those previously presented in FIG. **1** (e.g., intake manifold, compressor, turbine, etc.). In this way, no electrical components are used for the operation of the aspirator system **220** and/or the brake booster **210**. Motive air flows into the aspirator system **220** via the front end **202** and out the aspirator system **220** via the rear end **204**.

FIG. **3** shows a system **300** with an aspirator system **302** in fluid communication with a vacuum reservoir **342** of a brake booster **340**. The aspirator system **302** and the brake booster **340** may be used similarly to aspirator system **220** and brake booster **210** in the embodiment of FIG. **2**, respectively. As described above, the brake booster **340** may use stored vacuum from the vacuum reservoir **342** to amplify a braking signal from an operator depressing a brake pedal **348**. The aspirator system **302** may replenish the vacuum reservoir **342** in response to the vacuum of the reservoir decreasing below the minimum threshold vacuum. The aspirator system **302** and the brake booster **340** are fluidly connected and where the aspirator is fluidly coupled to an ambient atmosphere. The aspirator system **302** and the brake booster **340** are not in fluid communication with an engine and or any engine components (e.g., intake manifold, exhaust manifold, compressor, turbine, cylinders, etc). Dashed arrows depict a direction of motive flow through the aspirator system **302**.

The aspirator system **302** comprises four different aspirator generating geometries each of which may rely upon flowing motive air from a larger flow path to a smaller flow path, as will be described below. Speed increases and pressure decreases (e.g., vacuum increases) as air flows from the larger path to the smaller path. The four different geometries may be arranged in series and in fluid communication with each other to build vacuum across the aspirator system **302**. The aspirator system **302** comprises of four portions namely, a first aspirator portion **310**, a second aspirator portion **360**, a third aspirator portion **320**, and a fourth aspirator portion **330**. The first **310**, second **360**, third **320**, and fourth **330** aspirator portions generate vacuum during vehicle speeds greater than a threshold speed via ram air. Alternatively, vacuum may be generated during vehicle speeds less than the threshold speed when one or more of the fans **380** and **382** are activated to provide motive flow to the aspirator system **302**.

The fourth aspirator portion **330** is farther downstream (e.g., nearer a rear end of a vehicle) than the first **310** second **360**, and third **320** aspirator portions. An outlet **332** is located between outer **334** and inner **336** walls and is in fluid communication with an ambient environment through rear grills of a vehicle. Motive air flowing through the outlet **332** flows outside the vehicle and into the atmosphere. A path of the outlet **332** may be marginally bigger at an upstream end compared to at the rear end of the vehicle due to geometries of the outer **334** and inner **336** walls. A cross-section of the outlet **334** is substantially annular allowing motive air to flow out the rear end in a toroidal (ring) shape. It will be appreciated by someone skilled in the art that the outlet **334** may comprise other suitable shapes.

The outer **334** and inner **336** walls are spaced away from each other by a width of the outlet **332**. The outer **334** and inner **336** walls may be substantially cone-shaped (e.g., conical) with a substantially circular cross-section. The inner wall **336** may be coupled to the outer wall **334** via supports (not shown) located between and fixed to the walls. The walls are closer to each other near the rear end of the vehicle compared to near the front end. In other words, the width (e.g., a space) between the outer **334** and inner **336** walls gradually decreases toward the rear of the vehicle compared to near the engine. In this way, motive air flowing through the outlet **332** increases in speed and decreases in pressure (e.g., increases vacuum) as it approaches the rear end of the vehicle. In one example, the vacuum produced is equal to 5 kPa. Alternatively, the vacuum produced may be less than or greater than 5 kPa.

The third aspirator portion **320** may be a contiguous pipe **324** spiraling around a portion of the first portion **310** near a third aspirator portion outlet **326**. As described above, motive flows of the third portion **320** and the first portion **310** may merge at a region of confluence **354**. The third portion **320** receives motive flow via an inlet **322** in fluid communication with the second aspirator portion **360** located downstream of a first cooling fan **380** and a front grill.

Motive flow from the second aspirator portion **360** flows through the inlet **322** and into the pipe **324**. The motive flow flows through a passage of the pipe **324**, around a conical wall **328**, gradually decreasing in width, before entering the connecting passage **350**. The third portion outlet **326** is a narrowest portion of the passage of the pipe **324** in one example. A second portion outlet **326** is located between conical wall **328** and a connecting passage pipe **352** of the connecting passage **350**, where the connecting passage pipe **352** and the conical wall **328** get closer together toward a downstream end of the aspirator system **302**. The third portion outlet **326** is substantially ring shaped and directs motive air into the connecting passage **350** along the connecting passage pipe **352** in a similar ring shape. Motive air may be pulled through the third portion outlet **326** by vacuum generated at the third aspirator portion **330**. Thus, motive flow flowing out of the outlet **326** has a lower pressure than motive air flowing in the passage of the pipe **324**. Thus, the third aspirator portion **320** is shaped to generate a vacuum near the outlet **326** which aids in drawing motive air out of the third **320** and second **360** aspirator portions and ultimately may supplement vacuum generation in the second aspirator portion. Motive air from the inlet **322** flows in a substantially circular direction around the conical wall **328** protruding through an opening created by the spiral-shape of the pipe **324** before flowing into the region of confluence **354** at an upstream end of the connecting passage **350**.

The conical wall **328** comprises a circular cross-section, where the conical wall is widest at a conical wall inlet **329** and narrowest at a conical wall outlet **331**. The conical wall outlet **331** is concentric with the third aspirator portion outlet **326**, where motive flow from the conical outlet flows annularly inside of motive flow from the third portion outlet **326**. The conical wall outlet **331** and the third portion outlet **326** are also concentric with a first downstream passage (outlet) **316**, where motive flow from the downstream passage flows interior to flows from the conical outlet **331** and the third portion outlet **326**. By flowing motive flow into the region of confluence **354** in this way, vacuum is generated and able to assist vacuum formation in the first **310** and second **360** aspirator portions. The vacuum generated by the third aspirator portion is exactly 15 kPa in one example. Alternatively, the vacuum generated by the third aspirator portion may be greater than or less than 15 kPa. In this way, the vacuum generated by the third aspirator portion **320** is less than the vacuum generated by the fourth aspirator portion **330**.

The first aspirator portion **310** is farther upstream (e.g., nearest a front end of a vehicle) than the other portions of the aspirator system **302** in one example. In another example, the second aspirator portion **360** may be farther upstream than the first aspirator portion **310**. The first aspirator portion **310** is substantially linear with the first downstream passage **316** extending between the conical wall outlet **331** and the third outer portion **326**, as described above. The first aspirator portion **310** further comprises a first upstream passage (inlet) **314**, where a first venturi passage **312** is located between the first upstream **314** and first downstream **316** passages. The upstream passage **314** is located downstream of a second cooling fan **382** and a front grill of a vehicle, serving as an inlet for the first aspirator portion **310**. Motive flow flows through the venturi passage **312** where it increases in speed and decreases in pressure, resulting in a vacuum. Motive flow through the first aspirator portion along with vacuum generation at the first venture passage **312** is further promoted by vacuum created at the region of confluence **354** as described above.

The second aspirator portion **360** is substantially linear with a second downstream passage **366** fluidly coupled to the third portion inlet **322**. A second venturi passage **364** is located between a second upstream passage (inlet) **362** and the second downstream passage **366**. The second upstream passage **362**, venturi passage **364**, and second downstream passage **366** may be substantially identical to first upstream passage **314**, first venturi passage **312**, and first downstream passage **316**, respectively. Thus, these components are not re-introduced for reasons of brevity.

The brake booster **340** is fluidly coupled to the first aspirator portion **310** at a narrowest portion of the first venturi passage **312** via a first vacuum line **344**. The brake booster **340** is similarly coupled to the second aspirator portion **360** at a narrowest portion of the second venutri passage **364** via a second vacuum line **345**. The narrowest portions of the first venturi passage **312** and the second venture passage **364** may generate more vacuum than other portions of the venturi passage **312**. In one example, the vacuum generated at the narrowest portion is 40 kPa. Alternatively, the vacuum generated at the narrowest portion may be greater than or less than 40 kPa. In this way, the fourth aspirator portion **330** generates a greatest amount of vacuum, which increases a vacuum generated by the third aspirator portion **320** aiding vacuum generated by the first **310** and second **360** aspirator portions.

A first check valve **346** is located along the first vacuum line **344** and a second check valve **347** is located along the second vacuum line **345**, where the check valves are between the brake booster **340** and the first **310** and second **360** aspirator portions. The check vales may open and provide vacuum to the vacuum reservoir **342** simultaneously. In this way, a rate of vacuum replenishment of the brake booster **340** is faster than a rate of vacuum replenishment with only one aspirator portion. For example, the check valves may open when a vacuum of the vacuum reservoir **342** is less than a minimum threshold vacuum, which is based on a pressure of the first aspirator portion **310**. When the valves **346** and **347** are open, the first **310** and second **360** aspirator portions provide vacuum to the vacuum reservoir **342** by drawing air from the reservoir **342** into the first aspirator portion **310**, leaving the reservoir **342** void of gases.

Thus, generating vacuum in the aspirator system **302** includes receiving motive air through the first aspirator portion **310**, the second aspirator portion **360**, and the conical wall **328**. The motive air flows through geometries of the aspirator system **302** which are designed to increase vacuum generated by more upstream portions of the aspirator system. In this way, vacuum may be provided to a brake booster by flowing air through the aspirator system **302** without flowing the air to the engine or any other engine components.

Thus, in another embodiment an auxiliary aspirator system for providing vacuum to a brake booster may comprise venturi passages fluidly coupled to the brake booster with check valves located therebetween, and where the check valves are open based on a vacuum load of the brake booster. The aspirator system receives ram air (motive air) via the venturi passages and a conical pipe. A first venturi passage of the venturi passages is fluidly coupled to a volute-shaped pipe configured to assist in vacuum generation in the first venturi passage. A second venturi passage of the venturi passages is fluidly coupled to the conical pipe configured to assist vacuum generation in the second venturi passage. Outlets of the second venturi passage, the conical pipe, and the volute-shaped pipe are concentric, with the volute-shaped pipe outlet being the farthest outside and the second venturi passage outlet being the most inside. Air from the outlets may merge in a region of confluence before flowing through a passage to a downstream conical outlet. The first venturi passage, the second venturi passage, the volute-shaped pipe, the conical pipe, and the downstream conical outlet are configured to generate vacuum as air flows through the aspirator system. The first and second venturi passages may replenish a vacuum of the brake booster when a vacuum level in the brake booster is less than a vacuum produced by the first and second venturi passages. Air flowing through the aspirator system does not flow to any intervening components. Furthermore, the valves and other components of the aspirator system are not electrically actuated.

FIG. **4** shows a method **400** for operating an aspirator system for providing vacuum to a brake booster. The method **400** may further provide instructions for operating one or more cooling fans for providing motive air to the aspirator system during vehicle conditions producing insufficient motive air. Instructions for carrying out method **400** may be executed by a controller (e.g., controller **12** of FIG. **1**) based on instructions stored on a memory of the controller and in conjunction with signals received from sensors of the engine system, such as the sensors described above with reference to FIG. **1**. The controller may employ engine actuators of the engine system to adjust engine operation, according to the methods described below. For example, the controller **12** may adjust operation of one or more cooling fans (e.g., cooling fans **380** and **382** of FIG. **3**) during vehicle operation.

The method **400** may be described in reference to components previously presented. Specifically, the method **400** may be described in reference to vehicle **200**, brake pedal **212**, brake booster **340**, aspirator system **302**, and check valve **346** of FIGS. **2** and **3**.

The method **400** begins at **402** where the method **400** includes determining, estimating, and/or measuring current engine operating parameters. The current engine operating parameters may include engine speed, coolant temperature, engine load, vehicle speed, manifold air pressure, manifold vacuum, and air/fuel ratio.

At **404**, the method **400** includes determining if the coolant temperature is greater than a threshold temperature. The threshold temperature range may be based on a desired coolant operating temperature (e.g., 185° F.). Coolant temperatures below the threshold temperature may be too cold and lead to one or more of a catalyst not lighting off, increased condensate formation, and freezing. If the coolant temperature is less than the threshold temperature, then the method **400** proceeds to **406** to maintain current engine operating parameters and does not activate the cooling fans. The method may proceed to **410**, as will be described below.

If the coolant temperature is greater than the threshold temperature, then the method **400** may proceed to **408** to activate the cooling fans to provide cooling to an engine compartment. The fans may be variable speed fans such that a flow rate provided by the fans is controlled by a controller (e.g., controller **12**).

At **410**, the method **400** includes estimating a brake booster pressure. The brake booster pressure may be estimated based on a duration of brake pedal depression and an amount of vacuum replenishment, wherein a greater duration corresponds with a higher brake booster pressure and a greater amount of vacuum replenishment corresponds with a lower brake booster pressure.

At **412**, the method **400** includes determining if vacuum is desired by the brake booster. Vacuum may be desired if the brake booster pressure is less than a vacuum (e.g., minimum threshold vacuum) of a first aspirator portion of the aspirator system (e.g., first aspirator portion **310** of the aspirator system **302**). Additionally or alternatively, vacuum may also be desired based on the duration of brake pedal depression and miles driven. If vacuum is not desired, then the method **400** proceeds to **414** to maintain current operating parameters and does not open the check valve located between the brake booster and the aspirator system. Motive air may flow through the aspirator system despite the check valve remaining closed. In this way, motive air is continuously provided to the aspirator system while the vehicle is in motion.

If vacuum is desired, then the method **400** proceeds to **416** to determine if motive air is less than a threshold flow rate. The threshold flow rate may be based on a motive air flow rate capable of generating vacuum in the aspirator system. The motive air may be below the threshold flow rate for a vehicle speed less than a threshold speed (e.g., vehicle driving at a low speed or at a stop). The motive air may be greater than the threshold flow rate for a vehicle driving at mid or high speeds. If the motive air is not less than the threshold flow rate, then the method **400** proceeds to **418** to open the check valve and provide vacuum to the brake booster from the aspirator system. One or more cooling fans are not activated in order to provide motive flow to the aspirator system. However, it will be appreciated that the cooling fans may be activated based on other conditions (e.g., coolant temperature exceeding the threshold temperature). The check valve is automatically opened by a pressure of the brake booster being greater than a pre-loaded pressure of the check valve. As an example, the check valve may be spring actuated and a pressure of the spring is overcome when the brake booster pressure exceeds the threshold pressure (e.g., 40 kPa). The check valve is not opened by an electronic signal.

If the motive air is less than the threshold flow rate, then the method **400** proceeds to **420** determine if the cooling fans are off. If the cooling fans are already activated due to other vehicle conditions (e.g., coolant temperature is greater than the threshold temperature), then the method **400** proceeds to **418** as described above.

If the cooling fans are off and the motive flow is less than the threshold flow rate, then vacuum may not be produced by the aspirator system and the method **400** proceeds to **422** to activate the cooling fans. The controller may signal activation of the cooling fans in response to the determination of the motive air being less than the threshold flow rate. The cooling fans rotate and provide motive flow to both the first aspirator portion and a second aspirator portion of the aspirator system.

Additionally or alternatively, the cooling fans may not be activated in response to the motive flow being less than the threshold flow rate due to the coolant temperature being less than the threshold temperature. In this way, the fans remain inactive to prevent condensate formation and/or condensate freezing which may degrade engine performance under some conditions. Under other conditions, the cooling fans may be activated in response to the motive flow being less than the threshold flow rate and the coolant temperature being less than the threshold temperature to provide vacuum to the brake booster. Engine operation may be adjusted to prevent condensate formation and/or freezing by increasing EGR, retarding spark, decreasing an air/fuel ratio, increasing a primary injection pressure, increasing a second injection volume, and other suitable adjustments capable of increasing coolant temperature. Additionally or alternatively, the adjustments may further include disabling coolant flow. Furthermore, a rotation speed of the cooling fans may be reduced to a minimum speed capable of providing the desired flow to the aspirator system for producing vacuum. By doing this, cooling of the coolant is decreased while vacuum is generated by the aspirator system and provided to the brake booster.

At **424**, the method **400** includes opening the check valve and providing vacuum to the brake booster from the aspirator system. The method **400** may continue to operate the cooling fans until the motive flow exceeds the threshold flow rate or until the coolant temperature are less than the threshold temperature. Additionally or alternatively, the cooling fans may be continuously operated.

FIG. **5** shows a chart **500** depicting an example brake booster vacuum level based on vehicle operations and modifications of vehicle operations. Chart **500** shows brake pedal position at plot **502**, brake booster vacuum level at plot **504**, vehicle speed at plot **506**, cooling fan status at plot **508**, and check valve position at plot **510**. All of the above are plotted against time on the X-axis. Line **505** represents a minimum threshold vacuum in the brake booster vacuum reservoir. Line **507** represents a threshold vehicle speed unable to provide sufficient motive flow to the aspirator system to generate vacuum.

Prior to time t**1**, a vehicle may be moving in a steady state condition with moderate speed. Brake pedal is in a released (or "off") position and brake booster vacuum is sufficient, as indicated by the brake booster vacuum **504** being higher than the minimum threshold vacuum **505**. The check valve between the brake booster and the aspirator system is closed due to the sufficient vacuum in the brake booster. The brake booster and the aspirator system are not in fluid communication when the check valve is in the closed position. The cooling fans are not activated (or "off") due to sufficient motive flow being delivered to the aspirator system, as indicated by the vehicle speed **506** being above the threshold vehicle speed line **507**.

At t**1**, the brake pedal may be applied by the operator upon which vacuum in the brake booster is consumed to enable wheel braking. Between t**1** and t**2**, as the brake application continues, the brake booster vacuum decreases (e.g., a pressure in the brake booster vacuum reservoir increases). However, the level of vacuum within the reservoir remains above the minimum threshold vacuum **505** and the check valve remains closes. Due to the brake application, vehicle speed decreases but does not decrease to a vehicle speed less than the threshold speed **507**. Thus, sufficient motive air is provided to the aspirator system and the cooling fans are not activated.

At t**2**, the brake pedal is released and the vehicle resumes steady state travel conditions, similar to those prior to t**1**, between t**2** and t**3**. The brake booster vacuum remains above the minimum threshold vacuum **505** and the vehicle speed remains above the threshold speed **507** and as a result, the check valve remains closed and the cooling fans remain deactivated.

At t**3**, the brake pedal may be applied again. Brake pedal application at t**3** may be more forceful (e.g., depressed further and faster) as compared to the brake pedal application at t**1**. As a result, a steeper drop in vacuum level within the brake booster vacuum is observed during the brake application between t**3** and t**4**. However, the brake booster vacuum remains above the minimum threshold vacuum **505**. The vehicle speed decreases due to the brake application and falls below the threshold speed **507** (e.g., a low speed or vehicle stop). Vehicle speeds below the threshold speed **507** may not be able to provide the aspirator system with a sufficient motive flow for generating vacuum. However, the cooling fans remain in an off position because the check valve is not open. In this way, the brake booster does not desire vacuum and a sufficient motive flow is not desired by the aspirator system.

At t**4**, the brake booster vacuum falls below the minimum threshold vacuum **505**. In response, the check valve moves to an open position. The brakes may be released at t**4**. The vehicle speed remains below the threshold speed **507** resulting in an activation of the cooling fans to provide the desired motive flow to the aspirator system to generate vacuum. Between t**4**and t**5**, an operator may depress an accelerator pedal resulting in the vehicle speed increasing. The cooling fans remain active for a total duration of the vehicle speed being less than the threshold speed **507** in combination with the check valve being open. The generated vacuum from the aspirator system is applied to the brake booster until vacuum in the brake booster is above the minimum threshold vacuum **505**.

In one embodiment, additionally or alternatively, the brakes may not be released at t**4** and vacuum may be consumed for braking applications. As described above, the check valve is opened as the brake booster vacuum falls below the minimum threshold vacuum **505**. Thus, the aspirator system may provide vacuum to the brake booster simultaneously to the brake booster providing vacuum for braking applications.

At t**5**, the accelerator pedal remains depressed increasing the vehicle speed beyond the threshold speed **507**. The cooling fans are deactivated in response to sufficient motive air being provided for generating vacuum in the aspirator. Between t**5** and t**6**, the brake booster vacuum level continues to increase but remains below the minimum threshold vacuum **505**. The check valve is open. Thus, the aspirator system generates vacuum via motive flow produced from vehicular movement and provides the vacuum to the brake booster.

At t**6**, the brake booster vacuum surpasses the minimum vacuum threshold **505**. The check valve closes in response to the brake booster vacuum increase and the brake booster and aspirator system are no longer in fluid communication. After t**6** , the accelerator pedal may continue to be depressed resulting in the vehicle speed increasing. The brake pedal may be released. The check valve may be closed. The cooling fans may be deactivated.

In this way, a brake booster vacuum may be replenished without flowing air from a vacuum reservoir to an intake manifold or other engine component. An aspirator system generates vacuum with motive flow and provides the vacuum to the brake booster when a check valve is open. The check valve may be automatically opened when the vacuum of the brake booster is less than a minimum threshold vacuum. One or more cooling fans may be located upstream of motive flow inlets of the aspirator system to generate motive flow at low vehicle speeds and/or stops. By doing this, vacuum may be provided from the aspirator system to the brake booster during a spectrum of vehicle conditions. The technical effect of using an aspirator system and brake booster system fluidly separated from an engine and its components is to eliminate usage of a control valve or other control system device for the replenishment of vacuum to the brake booster.

An aspirator system for a vehicle includes a volute shaped aspirator with a linear aspirator protruding through a spiral of the volute aspirator, the linear aspirator comprising a venturi passage fluidly coupled to a brake booster, and where the aspirators are fluidly coupled to front or rear grills via a conical aspirator with no other intervening components located therebetween. In a first example of the aspirator system, the conical aspirator is the furthest downstream and the linear aspirator is the furthest upstream of the aspirators. In a second example of the aspirator system optionally including the first example, further comprising a check valve located in a passage fluidly coupling the brake booster to the venturi passage. A third example of the aspirator system optionally includes one or more of the first and second example, and further includes, the check valve opens in response to a vacuum of the brake booster being less than a minimum threshold vacuum. A fourth example of the aspirator system optionally includes one or more of the first through third examples, and further includes, the volute shaped aspirator and the linear aspirator further comprise inlets for receiving motive air flow from the front grill. A fifth example of the aspirator system optionally includes one or more of the first through fourth examples, and further includes, the inlets are located downstream of fans. A sixth example of the aspirator system optionally includes one or more of the first through fifth example, and further includes, the aspirators generate vacuum during vehicle speeds greater than a threshold speed.

A method for an aspirator system includes generating vacuum via motive flow in an aspirator system when a vehicle speed is greater than a threshold speed or when at least one cooling fan is activated, providing vacuum from the aspirator system to a brake booster in response to a check valve being open, and mixing suck flow from the brake booster with motive flow in the aspirator system and flowing the mixture directly out a rear grill without flowing the mixture through any other components. A first example of the method includes where activating the cooling fan is in response to the vehicle speed being less than the threshold speed. A second example of the method optionally including the first example further includes the check valve being closed when a brake booster vacuum is greater than a minimum threshold vacuum. A third example of the method optionally including the first and/or second examples further includes where generating vacuum includes flowing motive flow through a venturi passage, a spiral shaped passage, and an annular passage of the aspirator system. A fourth example of the method optionally including the first through third examples further includes activating the cooling fan is in response to a coolant temperature being greater than a threshold temperature. A fifth example of the method optionally including the first through fourth examples further includes activating the cooling fan in response a combination of a vehicle speed being less than the threshold speed and the coolant temperature being less than the threshold temperature further includes one or more or retarding spark, disabling coolant flow, and advancing spark timing.

An aspirator system of a vehicle comprising an engine with one or more cooling fans, an aspirator system with at least one inlet downstream of and in fluid communication with the one or more cooling fans, a first, second, and third aspirator portions of the aspirator system fluidly coupled and capable of receiving motive flow from a front grill and expelling the motive flow out through a rear grill and a brake booster comprising a passage with a check valve fluidly coupled with the first aspirator portions with no other intervening components located therebetween. A first example of the system includes where the first aspirator portion is a venturi passage. A second example of the system optionally including the first example and further includes where the second aspirator portion is a volute shape, and where the first aspirator portion extends through a spiral of the second aspirator portion. A third example of the system optionally including the first and/or second examples and further includes where the third aspirator portion is a cone shape with an outlet located between outer and inner walls of the third portion, where the outlet is an annular shape, and where a space between the outer and inner walls decreases toward the rear grill. A fourth example of the system optionally includes one or more of the first through third examples and further includes where a connecting passage fluidly coupling the first and second aspirator portions to the third portion. A fifth example of the system optionally includes the first through fourth examples and further includes where the first aspirator portion receives suck flow from the brake booster when the check valve is open and flows a mixture of the suck flow and the motive flow toward the rear grill. A sixth example of the aspirator system optionally includes one or more of the first through fifth examples and further includes where the first aspirator portion outlet flow is linearly shaped and the second and third aspirator portion outlet flows are annularly shaped. A seventh example of the aspirator system optionally includes one or more of the first through sixth examples and further includes where the check valve is spring loaded with a predetermined tension based on a minimum threshold vacuum. An eighth example of the system optionally includes one or more of the first through seventh examples and further includes where the check valve is not electrically actuated.

Note that the example control and estimation routines included herein can be used with various engine and/or vehicle system configurations. The control methods and routines disclosed herein may be stored as executable instructions in non-transitory memory and may be carried out by the control system including the controller in combination with the various sensors, actuators, and other engine hardware. The specific routines described herein may represent one or more of any number of processing strategies such as event-driven, interrupt-driven, multi-tasking, multi-threading, and the like. As such, various actions, operations, and/or functions illustrated may be performed in the sequence illustrated, in parallel, or in some cases omitted. Likewise, the order of processing is not necessarily required to achieve the features and advantages of the example embodiments described herein, but is provided for ease of illustration and description. One or more of the illustrated actions, operations and/or functions may be repeatedly performed depending on the particular strategy being used. Further, the described actions, operations and/or functions may graphically represent code to be programmed into non-transitory memory of the computer readable storage medium in the engine control system, where the described actions are carried out by executing the instructions in a system including the various engine hardware components in combination with the electronic controller.

It will be appreciated that the configurations and routines disclosed herein are exemplary in nature, and that these specific embodiments are not to be considered in a limiting sense, because numerous variations are possible. For example, the above technology can be applied to V-6, I-4, I-6, V-12, opposed 4, and other engine types. The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various systems and configurations, and other features, functions, and/or properties disclosed herein.

The following claims particularly point out certain combinations and sub-combinations regarded as novel and non-obvious. These claims may refer to "an" element or "a first" element or the equivalent thereof. Such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements. Other combinations and sub-combinations of the disclosed features, functions, elements, and/or properties may be claimed through amendment of the present claims or through presentation of new claims in this or a related application. Such claims, whether broader, narrower, equal, or different in scope to the original claims, also are regarded as included within the subject matter of the present disclosure.

The invention claimed is:

1. An aspirator system, comprising:

a volute-shaped aspirator with a linear aspirator protruding through a spiral of the volute aspirator, the volute aspirator comprising a first venturi passage and the linear aspirator comprising a second venturi passage and where the passages are fluidly coupled to a brake booster, and where the aspirators are fluidly coupled to front or rear grills via a conical aspirator with no other intervening components located therebetween.

2. The aspirator system of claim **1**, wherein the conical aspirator is the farthest downstream and the first venturi passage is the farthest upstream of the aspirators.

3. The aspirator system of claim **1**, further comprising a first check valve located in a first passage fluidly coupling the brake booster to the first venturi passage and a second check valve located in a second passage fluidly coupling the brake booster to the second venturi passage.

4. The aspirator system of claim **3**, wherein the check valves open in response to a vacuum of the brake booster being less than a minimum threshold vacuum.

5. The aspirator system of claim **1**, wherein the volute-shaped aspirator, the linear aspirator, and a conical opening further comprise inlets for receiving motive air flow from the front grill, and where the conical opening protrudes through the spiral of the volute-shaped aspirator.

6. The aspirator system of claim **5**, wherein the inlets are located downstream of fans.

7. The aspirator system of claim **1**, wherein the aspirators generate vacuum during vehicle speeds greater than a threshold speed.

8. A system comprising;

an engine with one or more cooling fans;

an aspirator system with at least one inlet downstream of and in fluid communication with the one or more cooling fans;

first, second, third, and fourth aspirator portions of the aspirator system fluidly coupled and capable of receiving motive flow from a front grill and expelling the motive flow out through a rear grill; and

a brake booster comprising a first passage with a first check valve fluidly coupled with the first aspirator portion and a second passage with a second check valve fluidly coupled with the second aspirator portion with no other intervening components located therebetween.

9. The system of claim **8**, wherein the first aspirator portion is a first venturi passage and the second aspirator portion is a second venturi passage.

10. The system of claim **8**, wherein the third aspirator portion is a volute shape, and where the first aspirator portion extends through a cylinder protruding through a spiral of the second aspirator portion with a conical pipe located therebetween and where outlets of the first aspirator portion, the conical pipe, and the third aspirator portion are concentric.

11. The system of claim **8**, wherein the fourth aspirator portion is a cone shape with an outlet located between outer and inner walls of the fourth aspirator portion, where the outlet is an annular shape, and where a space between the outer and inner walls decreases toward the rear grill.

12. The system of claim **8**, further comprising a connecting passage fluidly coupling the first, second, and third aspirator portions to the fourth aspirator portion.

13. The system of claim **8**, wherein the first and second aspirator portions receive suck flow from the brake booster when the check valve is open and flow a mixture of the suck flow and the motive flow toward the rear grill.

14. The system of claim **8**, wherein first and second aspirator portion outlet flows are linearly shaped and third and fourth aspirator portion outlets flows are annularly shaped.

15. The system of claim **8**, wherein the check valves are spring loaded with a predetermined tension based on a minimum threshold vacuum, and where the minimum threshold vacuum is based on a vacuum in the first and second aspirator portions.

16. The system of claim **8**, wherein the check valves are not electrically actuated.

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